*Glacier Bay National Park and Preserve, Alaska*

# Chapter 5: Components of the Set-Up Phase of Adaptive Management



In this chapter and the next we draw upon our case studies to illustrate the elements and processes of adaptive management in the areas of climate change, water, energy, and human impacts on the landscape. We concentrate on these themes for several reasons. They represent major issues and management challenges for the Department of the Interior and the nation at large. Each of the areas comprises a large collection of management challenges, with diverse stakeholders, complex interactions among physical, ecological, and social components, varying levels of uncertainty, and many opportunities for an adaptive approach. Finally, it is easy to see how management problems in each thematic area could benefit from adaptive decision making.

First, we revisit the elements in the set-up or deliberative phase of adaptive management (stakeholder involvement, objectives, management alternatives, predictive models, and monitoring protocols). Summary descriptions of the examples used here are found in the appendix.

## 5.1. Stakeholder involvement

Stakeholders bring different perspectives, preferences, and values to decision making. Managers can strengthen their decision making by involving stakeholders in framing a decision problem, identifying its objectives and models, and even developing and implementing monitoring protocols. It is important to have at least some stakeholder engagement in all the set-up elements of a project, and to continue that engagement throughout the project.

Stakeholder involvement varies greatly in the thematic areas considered here. In fact, adaptive decision making does not prescribe how many stakeholders are appropriate, who they should be, or how they should be organized. In some cases a few managers and decision makers may work directly with each other and the resource. In other cases a large number of stakeholders, including managers, scientists, regulatory organizations, private citizens, and others may interact in a highly structured and organized way.

It is not unusual for stakeholders to have widely divergent viewpoints about managing a resource. A critical challenge is to find common ground that will promote decision making despite disagreements about what actions to take and why. Failure to engage important stakeholders, and disagreement about how to frame a resource problem and identify its objectives and management alternatives, are common stumbling blocks. The challenges become more difficult with larger and more complex ecological problems that involve multiple stakeholders and a high degree of uncertainty (or disagreement) about how to value and manage the resource.

As with any endeavor that involves working with groups of people, principles and tools from the social sciences are needed (Endter-Wada et al. 1998, Heller and Zavaleta 2009). Failure to address social dynamics among stakeholders in a participatory process can set a project up for failure long before the advantages of adaptive decision making can be realized.

***Climate change.*** Landscape-scale climate change projects are just now emerging in the United States, and associated stakeholder groups are evolving. Because of the large scale of climate change and the magnitude of its potential consequences, climate change projects are likely to attract numerous stakeholders with strongly held views about the issues and the best approach to climate change mitigation and adaptation. Ensuring that stakeholder perspectives and opinions are heard and considered in strategy framing and implementation is a major concern.

The number of stakeholders could vary, from only a few for a local project involving a nature preserve, to a great many for regional projects involving multiple jurisdictions and management alternatives with wide-ranging impacts. Stakeholder groups will include federal, state, local, and tribal partners if the management options and resources involve their authorities. Stakeholders will be concerned about climate change risks, long-term sustainability of ecosystems and communities, and potential costs of mitigation and adaptation. The complexity of the issues, as well as the values and desires of stakeholders, calls for careful planning and engagement, often in a structured context of facilitated meetings and ongoing communications.

***Water resources.*** Stakeholder interests are tied to the many uses of water. Demand for water almost always exceeds availability, and this creates conditions for potential conflicts. For many projects a broad geographic area is affected by water management. The broader the area, the more likely it is to encompass many different stakeholder perspectives and commitments to specific water uses. For example, a river hydropower project can have an impact on natural resources both upstream and downstream of the dam, with numerous affected parties demanding to be recognized and engaged. The result is a complex milieu of stakeholder interests and the potential for conflict.

For all but the most localized examples, federal and state interests are involved in the adaptive management of water resources. Municipalities often have an interest in lakes and other standing water bodies for drinking water and other uses. Electric utilities, agriculture, recreation interests, and conservationists are almost always key stakeholders in the adaptive management of rivers and reservoirs for hydropower. Again, the high level of complexity means that stakeholder involvement needs to be well planned, and perhaps facilitated.

***Energy.*** Adaptive management projects are beginning to deal with established renewable technologies such as solar and wind power, with emerging renewable energy technologies such as wave power a step behind. The possibility of contention is likely to be high if the area covered by a project is large and the devices (e.g., underwater turbines, floating buoy-like devices, etc.) have the potential to affect protected species or local livelihoods. With more traditional energy projects involving fossil fuels (e.g., oil and gas), there are usually large numbers of active stakeholders, especially if species of interest or public lands are affected.

Stakeholders in energy projects usually include federal permitting and regulatory agencies such as the Bureau of Land Management and the Fish and Wildlife Service, along with state agencies, environmental groups, industry, recreational users, ranchers, and local citizens. There are often conflicting views about the importance of different management objectives like endangered species survival and economic return from extractive operations. Two core issues are the siting of new energy facilities and the operation of existing facilities. Because energy production is a strategic goal of DOI, stakeholder interactions must be facilitated in ways that lessen potential conflicts over these issues.

***Human/natural interface.*** As with the previous themes, the diversity and complexity of stakeholder groups can lead to multiple management objectives in apparent conflict, and in turn to conflicts among stakeholders. Single-agency projects with one or a few objectives (e.g., management of a single species of high concern) generally have fewer stakeholders and less potential for conflict. As the geographic scope of a project expands, so too does the universe of concerned parties. In small areas managed by a single agency or landowner (e.g., water management on a refuge wetland), project activities may have no effect on interests outside the project. Projects with a larger geographic and ecological scope probably involve a larger number of parties with their own perspectives and special interests; these projects need structured approaches for getting stakeholders involved.

## Examples of stakeholder involvement

***Laysan duck translocation and sea level rise***

The Laysan duck is an endangered species with breeding sites so restricted that any catastrophe, such as sea-level rise due to climate change, could result in extinction. To increase chances of species survival, managers from the Fish and Wildlife Service and the National Oceanic and Atmospheric Administration are preparing to manage the translocation of ducks adaptively in order to establish breeding populations on other unoccupied islands within the Papahānaumokuākea

Marine National Monument, northwestern Hawaiian islands. Stakeholders include the National Oceanic and Atmospheric Administration, the Fish and Wildlife Service, the U.S. Geological Survey, and Hawaiian state agencies, all of which share a primary objective of endangered species recovery. If translocation extends into the main Hawaiian islands, public meetings and outreach to further stakeholders may be needed.

***Glen Canyon Dam***

The Glen Canyon Dam on the Colorado River was authorized by Congress in 1956 and constructed in the late 1950s by the Bureau of Reclamation for the primary purposes of water storage and hydroelectric power production. Dam operations fundamentally altered the river ecosystem, and concerns related to impacts on downstream riparian ecosystems, recreation, and endangered species, particularly native fish, were driving forces for change in the operation of Glen Canyon Dam. After completion of an environmental impact statement required by the Grand Canyon Protection Act of 1992, the Secretary of the Interior approved the initiation of the Glen Canyon Dam Adaptive Management Program. The program brought together a broad spectrum of stakeholders with widely divergent views on river management under the framework and structure of the Federal Advisory Committee Act. The stakeholder group consists

of 25 members including federal and state agencies, Native American tribes, the Colorado River basin states, hydropower distributors and users, and recreational and environmental interests. The program makes recommendations to the Secretary of the Interior, and uses scientific investigations, experimental actions, and adaptive management principles to help inform recommendations about dam operations and other actions. The continuing focus of the program is to ensure that Colorado River flow regimes from Glen Canyon Dam meet the goals of supplying water for communities, agriculture, and industry and providing clean hydropower in a manner that protects the downstream resources as required by the Grand Canyon Protection Act of 1992.

***Blanca wetlands***

The Blanca wetlands site is a complex of shallow and deep ponds, marshes, and wetland systems managed by the Bureau of Land management in Colorado's San Luis Valley. It is maintained through a series of artesian wells, irrigation canals, and diversion ditches. Because of the relatively small scale of adaptive management in the Blanca wetlands, only limited stakeholder involvement is currently necessary. The Bureau of Land Management has partnered with the Colorado Division of Wildlife, the Fish and Wildlife Service, and Ducks Unlimited to restore and preserve habitats in the area. Bureau staff meet annually with a wetlands focus group that includes representatives of other agencies to identify priorities and issues associated with water availability and species needs in the larger wetland complex in the valley.

***Wyoming Landscape Conservation Initiative***

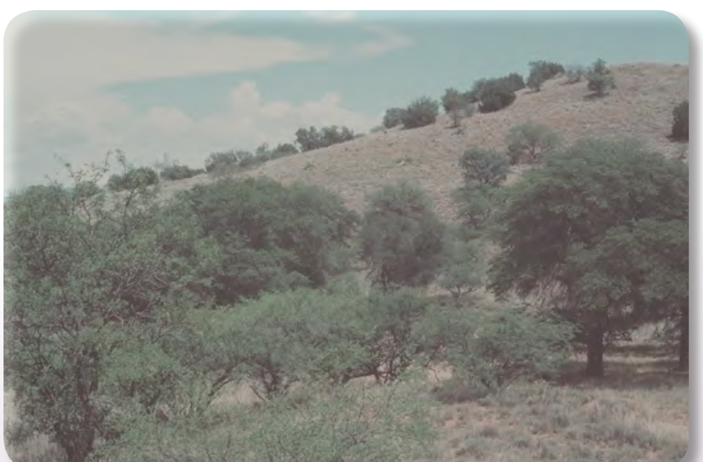
The ongoing development of public lands in southwest Wyoming for coal, oil, natural gas, and uranium since the late 19th century affects wildlife species such as the sage grouse, a candidate for federal listing as an endangered species, and wildlife habitats. The Wyoming Landscape Conservation Initiative was launched in 2007 to conserve and enhance wildlife habitat in areas of oil, gas, and other resource development. Stakeholders include federal agency collaborators such as the Bureau of Land Management, the U.S. Geological Survey, and the Forest Service, along with state agencies, counties, and other government organizations. Non-governmental organizations include environmental and recreation groups, as well as industry and landowner representatives.

***Adaptive management of waterfowl harvests***

Adaptive harvest management was developed to deal with uncertainties in the regulation of sport waterfowl hunting in North America. Early each year, the Fish and Wildlife Service announces its intent to establish waterfowl hunting regulations and provides the schedule of public rule-making. The agency director appoints a Migratory Bird Regulations Committee that presides over the process and is responsible for regulatory recommendations. The committee convenes public meetings during summer to review biological information and to consider proposals from regulations consultants, who represent the flyway councils. The flyway councils and the state fish and wildlife agencies they represent are essential partners in the management of migratory bird hunting. After deliberations by the committee and regulations consultants, the Service presents hunting-season proposals at public hearings and in the *Federal Register* for comment. Through this formal process, interested stakeholders have an opportunity each year to express their opinions and recommendations about harvest regulations and potential impacts on waterfowl populations.

***Las Cienegas National Conservation Area***

The Las Cienegas National Conservation Area in northern Arizona was once the historic Empire and Cienega ranches. The Sonoita Valley Planning Partnership (SVPP) was formed in 1995 to help the Bureau of Land Management develop a land-use plan covering both commercial grazing interests and ecosystem conservation. The participants include individuals from more than a dozen communities in southern Arizona, conservation groups such as The Nature Conservancy and Arizona Zoological Society, graziers, recreational user groups, and multiple federal, state, and other governmental organizations. SVPP and other partners work with the Bureau of Land Management on conservation area management and protection of buffer lands around the area.



***Everglades floodplain wetland management***

The 57,800-hectare A.R.M. Loxahatchee National Wildlife Refuge is a floodplain wetland at the northern end of the remaining Florida Everglades. This refuge is surrounded by 280,000 hectares of farmland on one side and residential areas for 6.5 million people on the other. The refuge serves a triple purpose of providing flood protection, water, and wildlife habitat (numerous threatened and endangered species, migratory birds, and other trust resources rely on refuge habitat). Refuge managers work with three major stakeholders at the federal, state, and local level: the U.S. Army Corps of Engineers, the South Florida Water Management District, and the Lake Worth Drainage District. These partners collectively manage water levels within the refuge to follow an established water regulation schedule, which comprises a set of operational rules for moving water into and out of the wetland on the basis of water levels in the marsh and the time of year. Refuge staff and managers use a variety of communication fora to exchange information relevant to water management actions.

***Fire fuel treatments in the Sierra Nevada***

Millions of hectares of forest in California are at risk from wildfires, and controversial management of fire fuels on Forest Service lands in the Sierra Nevada has generated disagreements and lawsuits since 1990. To help reconcile conflicts over fire fuels management, an adaptive management project is being used to implement the 2004 Sierra Nevada Forest Plan Amendment. The 7-year project evaluates how different forest vegetation treatments can slow fire spread and reduce fire intensity, within the constraints of maintaining water quality, habitat for the Pacific fisher and California spotted owl, and residential safety. Stakeholders include federal representatives from Forest Service regional offices, national forests, the Forest Service's Pacific Southwest Research Station, and the Fish and Wildlife Service; representatives from several state agencies such as CalFire and the California Department of Fish and Game; and a university science team with members from several University of California branches and the University of Minnesota.

## 5.2. Objectives

Successful implementation of adaptive management depends on a clear statement of project objectives, defined here as intended outcomes or performance measures to guide decision making and recognize success. Objectives represent benchmarks against which to compare the potential effects of different management actions. They also serve as measures to evaluate the effectiveness of management strategies, and they contribute to the reduction of uncertainty over time. Objectives influence the operation of adaptive management so much, and in so many ways, that it is unclear how adaptive decision making can happen without them.

Objectives in adaptive management often target particular goals or end results – for example, achieving a restoration goal. Some objectives are stated in terms of optimization – for example, maximizing long-term biological harvest or minimizing long-term costs of ecological recovery. Others involve specific criteria – for example, meeting a set of resource and management conditions. In all cases, objectives should be consistent with legal and regulatory requirements.

With large numbers of stakeholders there are usually multiple objectives, some of which may be in conflict. For example, objectives for a water release project might include the use of water for agriculture, power generation, recreation, and ecological sustainability, with the recognition that available water is insufficient to meet all these demands. Constraints imposed by agency-specific legal or regulatory requirements can lead to conflict among stakeholders and their objectives. The different missions of agencies can also create contention. Incorporating multiple values and measures adds complexity to the task of identifying objectives. Under these circumstances it is important to consider tradeoffs among potential objectives.

As mentioned in Chapter 1, adaptive management facilitates not only technical learning about ecological processes, but also institutional learning about management objectives and other adaptive management components. Double-loop learning gives an opportunity to reconsider project objectives over time, so they can be adjusted as needed when the resource changes or when stakeholder values and perspectives change. Double-loop learning is discussed in more detail in Section 2.7 and Chapter 6.

***Climate change.*** For climate change projects, objectives will fall into two broad categories: (*i*) mitigation of climate change by reducing or eliminating its causes (primarily by reducing emissions of greenhouse gases or sequestering carbon); and (*ii*) adaptation to the consequences of climate change. Reducing impacts on resources and buffering ecological processes and systems will be typical objectives. Because of deep uncertainties about the magnitude, timing, and even direction of climate change and resource responses, a special effort must be made to ensure that adaptive management objectives are meaningful, achievable, agreed upon by stakeholders, and relevant over time. Climate-induced changes in environmental conditions will complicate the process of setting management objectives by altering resource processes and dynamics in unpredictable ways (Williams and Jackson 2007, Knutson and Heglund 2011). The uncertainties surrounding climate change underscore the importance of maintaining the capacity to adjust project objectives and to learn quickly as climate patterns are revealed over time.

***Water resources.*** Most water resources can be used in diverse ways for multiple objectives. It is important to reach agreement on objectives, how to weight them, and how to account for the possibility of revising them over time as evidence about the resource system accumulates and stakeholder values evolve. Reconciling conflicting demands for limited water (such as dam releases to accommodate peak electricity demand versus flow regimes to maintain native fauna and flora downstream) requires compromise on initial objectives that can be refined and revised later through the process of double-loop learning.

***Energy.*** Obvious measures of importance in setting objectives are the amount and timing of energy production, though these measures sometimes serve as constraints in the framework of a project rather than objectives. Other important measures include impacts on the landscape from the siting of facilities, disturbance from infrastructure development (e.g., roads, power lines), ecological impacts from facilities operations, and the consequences of energy production for social and economic conditions in the area.

***Human/natural interface.*** Here, objectives may include goals to be attained within some time limit, minimization of management costs, maximization of resource benefits, and tradeoffs among multiple objectives to achieve acceptable levels of performance for each. For example, one might seek to minimize ecological damage (e.g., from pests) as well as the cost of management, or to maximize ecological attributes (e.g., a viable wildlife population that can accommodate sport hunting) as well as ecological processes (e.g., reproduction on the breeding grounds).

## Examples of management objectives

***Glen Canyon Dam***

The Glen Canyon Dam on the Colorado River was constructed by the Bureau of Reclamation for the primary purposes of water storage and hydroelectric power production. Public concerns regarding adverse impacts of dam operations on downstream resources, including endangered native fish, led to changes in dam operations and passage of the 1992 Grand Canyon Protection Act. The Glen Canyon Dam Adaptive Management Program was adopted to meet requirements in the Grand Canyon Protection Act. The program's objectives express stakeholders' views and priorities regarding the operation of Glen Canyon Dam and other related activities. Glen Canyon Dam is operated under applicable federal law, including the Law of the Colorado River and the direction provided by Congress in 1992 to operate the dam in a manner that protects, mitigates adverse impacts on, and improves the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including but not limited to natural and cultural resources and visitor use.

***Offshore wind farm on the Atlantic coast***

Offshore wind facilities may occupy as much as 65 square kilometers or more of ocean, with turbines over half a kilometer apart. Turbines typically are installed on a hard substrate, and are connected by cables to a service platform. Concerns relate to fisheries and boating recreation in the vicinity, as well as possible impacts on bats, birds, and marine life. In deciding where to site such a wind facility, objectives to maximize energy production and minimize costs are weighed against objectives to minimize impacts on important trust species, maintain fish and shellfish harvests, and minimize impacts on marine transport and recreation in coastal areas.

***Predator control at Cape Lookout National Seashore***

Human activity at Cape Lookout National Seashore has led to an increasing raccoon population and an increase in predation of shorebird nests. Reducing the raccoon population can help to meet the objective of increasing shorebird reproductive success, within the constraint of the park's larger mandate to preserve all native species at viable levels. An adaptive approach to managing predator abundance has been developed to (*i*) minimize the number of raccoons removed, (*ii*) keep the raccoon population above a minimum threshold, and (*iii*) increase oystercatcher productivity above a set threshold.

***Cape Cod National Seashore wind turbines***

The Cape Cod National Seashore plans to install several wind turbines to reduce greenhouse gas emissions from park facilities, as part of its mission to serve as a regional model of environmental sustainability. Objectives focus on maximizing wind power within the constraints of protecting birds and bats. If negative impacts on fauna are found to be unavoidable, alternate renewable energy sources (e.g., solar) will be considered.

***Adaptive harvest management***

Adaptive harvest management was developed to deal with uncertainties in the regulation of sport waterfowl hunting in North America. The Migratory Bird Treaty Act of 1918 (as amended) authorizes establishment of annual hunting regulations for migratory birds. Managers try to maximize the value of long-term cumulative harvest, with an implicit goal of sustainability. Harvest value has been defined as a function of harvest and other performance metrics. For mid-continent mallards, managers want to maximize long-term cumulative harvest; the annual harvest is weighted proportionally less if population size is expected to fall below the goal set by the North American Waterfowl Management Plan. Defining harvest value in this way decreases the likelihood of population sizes below the plan's goal. An additional constraint on long-term harvest potential eliminates consideration of closed seasons as long as predicted population size is at least 5.5 million.

***Columbia River chinook salmon***

Numerous dams have been established on the Columbia River for hydropower, irrigation, and flood control, but they have adverse impacts on native fish and have negatively affected spawning and recruitment of fall-run chinook salmon. Public utility districts of the middle Columbia River work with federal and state agencies and Native American tribes to set priorities for power generation and fish and wildlife protection. Dam relicensing by the Federal Energy Regulatory Commission highlighted the need to protect chinook spawning areas in the Hanford Reach of the Columbia. An adaptive management working group representing the stakeholders established a procedure for water releases to minimize the risk that chinook breeding areas would dry out from water fluctuations in the river, within the constraint of meeting energy demands. To achieve this objective, maximum and minimum daytime flow rates during the fall spawning season were needed to limit spawning at high elevations (which dry out as water levels drop), while at the same time retaining enough water on the lower spawning areas to allow successful spawning.

## 5.3. Management alternatives

Adaptive decision making requires the clear identification of a set of potential alternatives from which to select an action at each decision point. Some actions might affect the resource directly – for example, harvest, stocking, or habitat alteration. On the other hand, actions might have indirect effects – for example, regulations to limit overuse. A set of potential actions might consist of different levels of a single type of action, such as a range of harvest rates. Alternatively, the set might include actions of different kinds, such as predator control, understory thinning, and recreational use.

Learning and decision making both depend on our ability to recognize differences in the consequences of different actions. Selecting potential actions that have distinctly different consequences offers the possibility of comparing and contrasting them in order to choose the best one.

***Climate change.*** Potential management actions for climate change range widely, from regulation of resource use, to physical alteration of ecosystems and ecological processes, to translocation of species. Actions can be expressed in terms of broad strategies implemented over an extended time, or limited interventions aimed at particular resource issues. Management strategies can be designed to respond to changeable climatic conditions as well as changeable resource states. For example, a particular strategy for climate adaptation or mitigation might be designed specifically for one particular climate change scenario, but not for others. For any given project, the challenge will be to identify a useful set of climate scenarios, link them to relevant management options, and decide on a particular option.

***Water resources.*** Management alternatives for water resources often involve controls on water inputs, outputs, and allocation for competing uses. Other management options include actions that focus on maintaining or improving water quality, or retaining water in order to control floods. Management strategies can involve direct controls (e.g., releasing specific amounts of water for wetlands or river management) or indirect controls (e.g., regulating runoff of agricultural chemicals into streams).

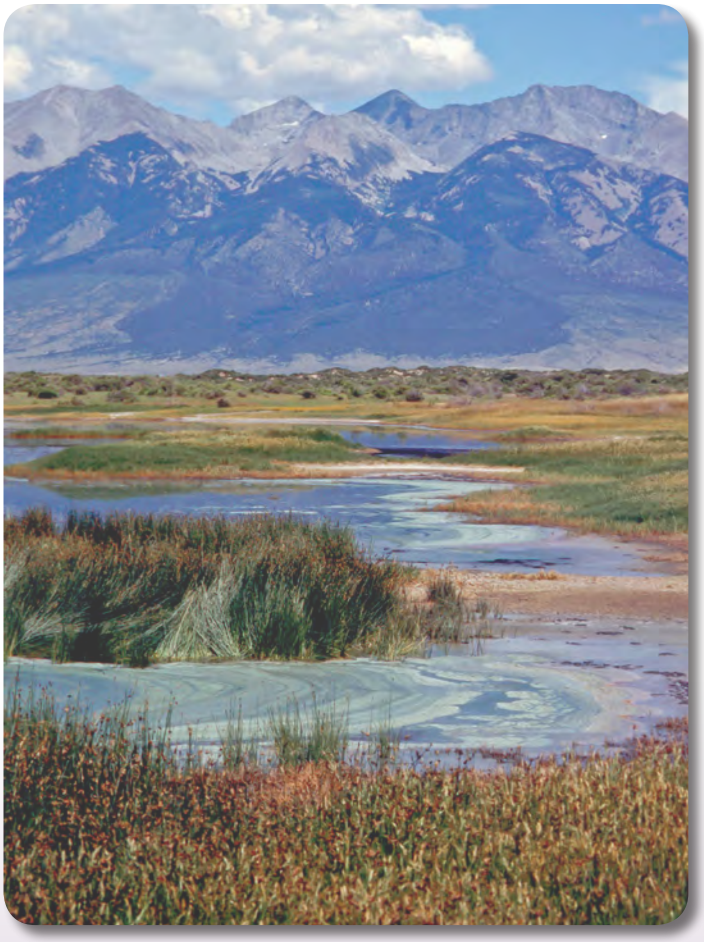
***Energy.*** Management alternatives for energy projects can be divided conveniently into (*i*) decisions about siting of new facilities, (*ii*) decisions about the development of supporting infrastructure (roads, power lines, pipelines), and (*iii*) decisions about the operation of facilities (timing and amount of energy production). A particular project might include any combination of these management elements.

***Human/natural interface.*** For biological and ecological systems, management alternatives may have direct effects on the resource state, or on processes and vital rates such as mortality, reproduction, or migration. Management actions can also have indirect effects – for example, regulatory actions can restrict resource use through permits, quotas, license sales, etc. Management options might also focus on organism growth, population management, habitat alteration, control of human disturbance, and similar interventions.

## Examples of management alternatives

***Blanca wetlands***

The Blanca Wildlife Habitat Area in southern Colorado encompasses over 6,200 hectares of marshes, ponds, and periodically flooded basins called playas,



which provide habitat for a wide variety of wildlife and plant species. The management plan for the area emphasizes its use by waterfowl, shorebirds, and amphibians. The Bureau of Land Management manages habitat with artesian water, canals, and diversion ditches, and annually adjusts seasonal habitat availability for particular species groups. Periodic flooding of playas produces high densities of insects and vegetation critical to wetland birds. Periodic drying of large wetland basins is also important in order to mimic the natural hydrology that supports ecological processes such as plant succession. Each year, managers release water from artesian wells into freshwater marshes and ponds. The amount and timing of water released are chosen each season from a range of possible alternatives related to annual water quality objectives, as well as provision of sufficient irrigated wetland areas to compensate for whatever basins are undergoing periodic drying. These habitat manipulations affect waterfowl, shorebird, and amphibian populations, which are the ultimate management targets.

***Solar project siting and permitting***

In California, proposed industry-grade solar energy projects range in size from 200 to 3,200 hectares, and may have a major impact on natural resources. The land and resources within a project boundary are affected by the placement of solar collectors, development of service roads, and mowing of vegetation. Wells may be dug at a site to obtain the water needed to wash the collectors regularly. In addition, rainwater retention basins may be

developed, which can interfere with desert sand transport cycles. Because flat terrain is necessary, projects are often built on valley floors and thus can affect nearby alluvial fans. An adaptive management application for a permit system for solar energy development might use systematic implementation and evaluation to learn about the best ways to site new projects. For example, a solar farm could be divided into two segments, or sited in an existing brown-field area, or designed as a long thin strip perpendicular to the direction of sand transport. Monitoring the impacts of a particular design at one site could provide information about potential impacts at subsequent sites.

***Native prairie restoration in national wildlife refuges***

Native prairies in national wildlife refuges on the northern Great Plains are being invaded to varying degrees by plants such as smooth brome and Kentucky bluegrass, the result of decades-long suppression of natural disturbance. By reintroducing disturbance, refuge managers hope to control invasive plants and restore a high proportion of native species. Disturbance treatments directly modify the system state (grazing or haying to remove cover of invasive species) or affect biological process rates (e.g., burning to suppress growth rate of invasive species). Managers choose annually one of five main management alternatives – burn, graze, hay, burn/graze, or rest. For each alternative, there are broad sideboards on timing and intensity.

***Endangered mussel translocation***

Northern riffleshell mussels, along with many other freshwater mollusks, have disappeared from their former range to such a degree that they are now federally listed as endangered. Translocation is an important means of promoting the recovery of these species. When bridge construction on the Allegheny River resulted in a formal Endangered Species Act consultation with the Fish and Wildlife Service, a mussel relocation program was mandated. The Allegheny riffleshells were translocated to the Big Darby Creek, Ohio, in an effort to augment a small population within the species' historic range. Management alternatives involved interconnected decisions about the number of mollusks to be moved, the genetic and demographic composition of the translocated population, optimal release sites with preferred microhabitats and host fish, methods for minimizing disease transfer, and the season for transfer. Individuals are fitted with miniature transponders to allow the monitoring of translocation success. Information gained from this translocation will be directly applicable to future mussel restoration efforts.

***Everglades floodplain wetland management***

The interior marsh of the A.R.M. Loxahatchee National Wildlife Refuge is surrounded by a perimeter canal that transports water in and out of the floodplain wetland. The canal carries urban and agricultural stormwater runoff. Although the stormwater has been partially treated to remove excess nutrients, the level of phosphorus is still high. Refuge staff are working with partners to minimize the intrusion of nutrient-rich water into the marsh. Management alternatives consist of different combinations of canal-water inflows and wetland outflows in relation to various water depths. Permanent transects are set up to monitor movement of nutrient-enriched water from the canal into the heart of the wetland.

***Five Rivers forest landscape management***

The Oregon coastal range forests are some of the most productive in the temperate zone. Forest Service lands in this area were set aside mainly for late-successional and riparian habitat in the Northwest Forest Plan. Questions emerged about how to grow and improve habitat, especially on the existing forest plantations that make up about half the forest area. Collaborations among state and federal agencies and public groups resulted in the development of three management strategies that were included in an environmental impact statement, each thought to be scientifically valid given the uncertainties about achieving objectives. One strategy emphasizes closing roads permanently and allowing natural disturbances to thin stands, while allowing late-successional and riparian habitat to "recover naturally." A second strategy keeps roads open and allows repeated entries to thin plantations and add wood to streams. A third strategy focuses on closing roads after more aggressively thinning stands and aiding riparian habitat, and then reopening roads 30 years later to repeat the cycle. The strategies were implemented on 12 landscape areas of 485 hectares each (three strategies and four replicates) of national forest lands.

***Coastal wetland impoundments and potential sea level rise***

Many coastal wildlife refuges maintain wetland impoundments to enhance habitat and attract large numbers of shorebirds, waterfowl, and other wildlife. Rising sea level is a threat to these impoundments and their complex dike systems. Adaptive management of impoundments that are threatened by sea level rise might entail management alternatives such as: (*i*) manipulation of hydrology (e.g., by infrastructure improvements) and vegetation to meet current conservation targets; (*ii*) identification of new conservation targets and a new suite of management practices for them; or (*iii*) removal of the infrastructure and restoration of the impoundment to a naturally functioning wetland community. The management actions might consist of direct habitat alteration with different levels of a single type of intervention (such as alterations to dikes), or different types of interventions (such as planting vegetation versus removing infrastructure). The actions would be expected to result in different numbers of waterbirds and wildlife, the resources ultimately targeted by management.

***Biscuit Fire landscape management after the wildfire***

The Biscuit fire burned about 200,000 hectares in southwestern Oregon. Much controversy surrounded how to respond to the burning of vast areas of late-successional forest. Management strategies were openly debated in major news outlets and included dueling scientists, but official stakeholder input took place according to the National Environmental Policy Act process. An interdisciplinary team proposed a management study that compares three strategies: (*i*) focus on natural succession without salvage logging; (*ii*) salvage dead stands according to forest plan guidelines, then replant Douglas fir and control competing vegetation to grow large trees quickly; and (*iii*) reintroduce prescribed fire and plant more fire-resistant pines after salvaging stands as in the second strategy. These strategies were implemented across 14,568 hectares in 12 landscape areas of 1,214 hectares each (three strategies and four replicates) with some variations because of changes in economics caused by litigative delays. About 3,600 hectares of the study are on Bureau of Land Management lands; the remainder are on national forest lands.

***Adaptive harvest management***

Adaptive harvest management was developed to deal with uncertainties in the regulation of sport waterfowl hunting in North America. Each year the Fish and Wildlife Service establishes "framework" regulations for waterfowl hunting that are flyway-specific. The frameworks specify the earliest and latest dates for hunting seasons, the maximum number of days in the season, and daily bag and possession limits. States select


hunting seasons within the bounds of these frameworks, usually following their own processes for proposals and public comment. With the advent of an adaptive approach to harvest management in 1995, the number of potential frameworks was limited to three, which were characterized as restrictive, moderate, and liberal regulations. These three regulatory frameworks, along with the possibility of a closed season, constitute the management alternatives available during each year's process for setting waterfowl hunting seasons.

***Yosemite toads and livestock grazing***

The Yosemite toad, an altitudinal endemic amphibian of forests in the Sierra Nevada range, is a candidate species for listing under the Endangered Species Act. Because the toads are associated with shallow water in high montane and subalpine meadows, livestock use of wet meadows may significantly affect toad populations. The U.S. Forest Service is using experimental management to examine the relationship between grazing intensity and toad occupancy in livestock grazing allotments and ungrazed meadows in national forests. The four alternative management treatments are: (*i*) grazing in accordance with current stream-bank disturbance standards across an entire meadow; (*ii*) exclusion of livestock from wet areas within a meadow; (*iii*) no grazing in a meadow; and (*iv*) no grazing in a historically ungrazed meadow. Results will provide recommendations for future livestock grazing management to enhance survival and recruitment of the toad.

***Agriculture experimentation***

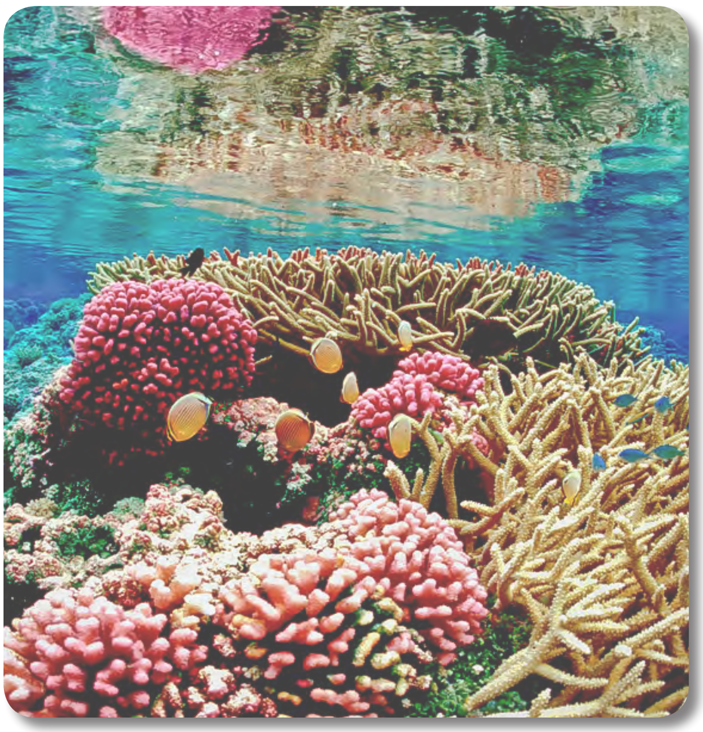
Agriculture provides many examples of experimental management. A typical problem involves uncertainty about which of several agricultural practices (different grains, fertilizers, crop rotation patterns, etc.) can produce higher and more consistent yields in an area. A management design might involve application of different agriculture practices in different fields, with some or all the features of an experiment (i.e., randomization, replication, and controls). Field applications often use randomized or randomized block designs. The process becomes adaptive when the elements of the adaptive management framework are used: objectives are clearly stated, potential outcomes are specified, monitoring protocols are decided, the method of learning is explicit, and the results of the experiment are used to update understanding and guide future agricultural practices.

***Fire fuel treatments in the Sierra Nevada***

Millions of hectares of forest in California are at risk from wildfires, and management of fire fuels on Forest Service lands in the Sierra Nevada has resulted in decades of controversy. To help reconcile conflicts, an adaptive management project is being used to implement the 2004 Sierra Nevada Forest Plan Amendment. The 7-year project evaluates how different forest vegetation treatments can slow fire spread and reduce fire intensity, within the constraints of maintaining water quality, wildlife habitat, and residential safety. The project involves reduction of fire fuels in a series of patches by use of strategically placed area treatments at the landscape level. Across approximately 17,200 hectares, 1,860 hectares are being considered for treatment alternatives that include (*i*) thinning and biomass removal by tractor, (*ii*) mastication, or (*iii*) prescribed burning. Decisions involve size, location, and intensity of treatments. Within treatments, different silvicultural prescriptions identify the species, size, and spatial arrangement of trees to be removed in order to achieve specified crown spacing, tree density, or canopy cover.

***Great Barrier Reef marine reserve management***

The Great Barrier Reef is a 2,000-kilometer-long complex of coral reefs and other ecosystems such as coastal seagrass beds and diverse sea-floor habitats covering 350,000 square kilometers off the northeast coast of Australia. A national marine park, it contains the world's largest network of marine reserves, which are designed systematically at a regional scale. Adaptive management is being used to restore ecosystem structure (e.g., widespread recovery of depleted fish stocks) and to prevent ongoing degradation (e.g., reduced coral mortality). The Great Barrier Reef Zoning Plan 2004 focuses on apex predators (reef sharks), commercially fished species (coral trout, redthroat emperor), and species of conservation concern (marine turtles, dugongs). Management incorporates a range of alternatives including spatial management with different levels of zoning (general use areas for trawling and gill-netting; no-trawling areas; limited-fishing areas; no-take areas; and no-entry areas); and within fished zones, nonspatial strategies including fishing gear restrictions (e.g., bycatch reduction and turtle excluder devices) and explicit management of fisheries (e.g., licenses, fish size restrictions, commercial quotas, temporal closures during spawning).



## 5.4. Predictive models

Models play a critical role in adaptive management, as expressions of our understanding of the resource, engines of ecological inference, and indicators of the benefits, costs, and consequences of alternative management strategies. Importantly, they can represent uncertainty (or disagreement) about the resource system. In the context of management, models project the consequences of different management interventions over time and help to examine how each management intervention might achieve objectives.

There are few restrictions on the number and kind of models used for adaptive management. However, certain features are required. The models must characterize resource changes over time, as the resource responds to fluctuating environmental conditions and management actions. They should embed hypotheses that are relevant to the management problem. To the extent needed, they should incorporate the forms of uncertainty described earlier. Finally, they must differ in the responses they predict as a result of management, for only then will it be useful for management to clarify which model best describes resource structure and function.

*In the context of management, models project the consequences of different management interventions over time and help to examine how each management intervention might achieve objectives.*

In general, as the scale and complexity of the ecological system and the management problem increase, larger and more complex models are needed to characterize the problem. Complexity and large dimension can be serious challenges to using models effectively. Nonetheless, many of the projects in this guide involve complex features and linkages, as well as many uncertainties in the associations between management and outcomes. These features require thoughtfulness and collaboration in the selection and formulation of models.

***Climate change.*** Climate change can be usefully characterized in terms of external environmental drivers such as temperature and precipitation regimes, wind patterns, cloud cover, etc. These factors are the most immediate expressions of a changing climate, and they can be incorporated as external drivers in resource models. In some cases potential climate variations can be treated as simple hypotheses about the pattern of change and responses of the resource. In other cases climate variations can be expressed as climate scenarios and uncertainties, or incorporated along with management actions into expressions of ecological processes.

The treatment of climate change must involve, either implicitly or explicitly, the characterization of instability (technically, non-stationarity) described in Chapter 4. Structural changes in natural resource systems are inherited from climate change, along with uncertainties about the size and even the direction of change. One way to incorporate the effect of climate change in modeling is to express different trajectories of the climate drivers (see Figure 4.1) as different climate scenarios.

Because of the scale at which climate change is thought to operate, its impact acts most directly on landscapes, by means of changes in landscape structure and function. Landscape changes in turn provide context for climate-driven changes in ecological relationships. Models can incorporate landform and land-use changes as well as ecological attributes. Structural uncertainty can be expressed as different forms of these patterns of change.

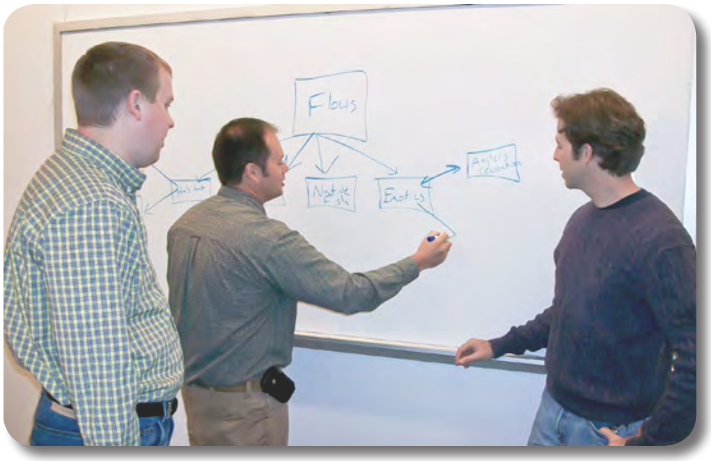
***Water resources.*** A natural modeling framework for water resources is a balance equation that accounts for (*i*) flows into a water body from runoff, subsurface water movement, and drainage from streams and rivers; (*ii*) movement of water out of the water body, due to surface and subsurface drainage and evaporation; (*iii*) attributes of the standing volume of water at any point in time; and (*iv*) ecosystem functions related to water conditions and management. Models of moving water focus on hydrodynamics, characterized by water velocity and other dynamic factors. Hydrodynamic effects on stream and river beds, banks, and riparian zones, and the ecological changes that occur in response, can also be included. Models of standing water bodies incorporate attributes like changes in water volume, nutrient cycling, heat flow and temperature patterns in the water column, water turbidity and quality, and the organisms in the water body. Structural uncertainties are often related to the ecological functions that drive these features.

***Energy.*** Models of energy development and use focus on (*i*) the selection of sites for infrastructure development and (*ii*) the operation of existing energy facilities. The framework for site selection differs somewhat from that for operations. A site, once selected, is developed and remains in place for the indefinite future. Modeling of site selection involves decisions about where to locate future sites on the basis of what is learned from follow-up monitoring of existing sites. Important components of this kind of model include habitat structure and function at potential sites, patterns of habitat fragmentation, and impacts on plants and animals. Structural uncertainties can be represented by different forms of these patterns and processes.

Facility operations at a specific site are seen as an ongoing process that incorporates what has been learned from past operations into ongoing management decision making. Issues of concern for these models include habitat alteration, timing and frequency of disturbances, and impacts of operations on flora and fauna in the area. Again, different forms of these patterns and processes can be used to express structural uncertainties.

***Human/natural interface.*** The very large class of natural resource issues related to this theme covers activities like habitat alterations and stocking or removal of plants and animals across a wide range of geographic and ecological scales. Models can be quite varied, with many different methodological approaches and details of structure and mechanism. Many models focus on the management of individual species or local habitats, while others address much broader issues such as biodiversity or ecosystem integrity. The underlying framework of a balance equation (for energy, mass, or number of organisms) is common. Structural uncertainties are represented by hypothesized forms of the processes that drive resource changes over time.

Like climate change, large-scale human interventions can induce unstable (i.e., non-stationary) resource dynamics. In both cases instability of resource behaviors presents new complications and challenges in modeling natural resource dynamics and formulating forward-looking strategies.



## Examples of models

***New England shrub habitats on refuges***

Shrub communities on national wildlife refuges in the northeast are important habitats for migrating land birds and the New England cottontail rabbit, a candidate for listing under the Endangered Species Act. Fish and Wildlife Service managers use adaptive management to control the invasive plants that degrade native shrub communities and reduce native stem densities and berries required by rabbits and birds. A key uncertainty is how much effort is needed to restore native shrub communities successfully. Two alternative models are aligned with treatment options that include different combinations of mechanical and chemical controls to reduce invasive plants. The models incorporate different mechanisms of change for key shrub attributes that can influence bird and rabbit populations (e.g., berry density, stem density, community composition), along with predictions about how these attributes will change in response to restoration treatments.

***Laysan duck translocation***

The Laysan duck is an endangered species so restricted that any catastrophe, such as sea level rise due to climate change, could result in extinction. To increase the chance of its survival, U.S. Geological Survey scientists and Fish and Wildlife Service managers are developing a framework for adaptively managing translocation of ducks in order to establish populations on other islands in the northwestern Hawaiian islands. To consider the potential consequences of different translocation actions, a modeling team is building occupancy models

to predict long-term persistence of duck populations. The models are linked to a framework for optimizing management actions on the basis of the resources available for conducting translocation. The models describe important relationships and uncertainties in the system, which include catastrophic events (e.g., tsunamis), disease outbreaks, accidental predator introductions, and habitat limitation or carrying capacity (and its relationship to sea-level rise) as the primary drivers of duck population dynamics. Island areas are classified on the basis of whether or not they are currently occupied and if unoccupied, whether they are suitable to receive translocated ducks. A unique version of the occupancy model is applied to each island in order to predict probabilities of transition between occupancy states given the conditions on that island (e.g., the altitude of habitat areas on the island). Island models will be linked through removals or additions of translocated ducks, and through large-scale events (e.g., a catastrophic storm hitting one island will be more likely to hit nearby islands). The optimization framework allows managers to investigate which combination of translocation actions results in maximum persistence and occupancy across sites.

***Lower Flint River basin fishes and drought***

To conserve water during critical drought periods, the state of Georgia has established the Flint River Drought Protection Act. The decision about where best to conserve water is complicated by uncertainty about ecosystem responses to changes in stream flows. For an adaptive approach to managing flows in the lower Flint River basin, models were built to evaluate the effects of different water use patterns. Four models incorporated four different hypotheses about the influence of stream flow on the colonization and persistence of fishes. The models represent different biological mechanisms, and they are used to estimate changes in species-specific fish distribution patterns under four simulated water-use scenarios. Learning is facilitated by the comparison of different predictions by the models and the actual fish distribution patterns derived from monitoring data.

***Florida scrub-jay habitat***

Endemic species like the endangered Florida scrub-jay that depend on a mosaic of scrub habitat have declined significantly as the coastal scrub ecosystem has been changed by fragmentation and fire suppression. Federal and state biologists have begun an adaptive management program to use fire and mechanical means to restore vegetation structure in order to improve the habitat for scrub jays. To represent the potential effects of various management alternatives, habitat models use Markovian transition models to predict rates of vegetation transition

between successional stages, while linked occupancy models predict the response of scrub-jays to the vegetation dynamics. These integrated models are optimized to identify the best sequence of management actions to meet objectives related to increasing the viability of the scrub-jay population.

***Etowah River endangered stream fishes***

Urban development north of metropolitan Atlanta threatens endangered stream fishes in the Etowah River. The major aquatic stressor is storm water runoff, with additional impacts from sedimentation, road and utility line crossings, riparian buffer loss, and reservoir impoundments. The Etowah Habitat Conservation Plan, presented to the Fish and Wildlife Service for approval, mandates adaptive management to help local governments deal with urban development while protecting aquatic resources. Occupancy models were constructed to link population indices of three federally listed darters to an indicator of storm water runoff that represents the amount of paved area. Modeling included spatially explicit expressions of probabilities of species occurrence and abundance for different urban development scenarios under the habitat conservation plan. The models are used to predict where the darters are expected to maintain strong populations and where they are expected to decline, for each scenario of future urban growth. Monitoring will provide new observations of species response to development and thus allow the model predictions to be compared with actual data on changes in species occurrence.

***Adaptive harvest management***

Adaptive harvest management was developed to deal with uncertainties in the regulation of sport waterfowl hunting in North America. Since its inception in 1995, the Adaptive Harvest Management Program has focused principally on the population dynamics and harvest potential of mallards breeding in mid-continental North America. Four alternative population models capture uncertainties regarding the effects of harvest and environmental conditions on mallard abundance. The models result from combining two mortality and two reproductive hypotheses. The mortality hypotheses express alternative views about the effects of harvest on annual survivorship, and the reproductive hypotheses represent alternative views of density-dependent population regulation. Under all four models, reproductive rate is modeled as a function of the number of ponds with water on Canadian prairies in May. Annual changes in pond numbers are represented as a first-order autoregressive process. Different predictions from each of the four models represent uncertainty about population dynamics.

***Native prairie restoration in national wildlife refuges***

By reintroducing disturbance in native prairies, refuge managers hope to control invasive plants and restore a high proportion of native species in national wildlife refuges invaded by smooth brome and Kentucky bluegrass. Annually collected data on prairie composition allow managers to classify sampling areas into one of 16 categories. Four competing models express different hypotheses about how the individual components of a grassland respond differentially to treatment (e.g., models generally assume that rest is to some degree detrimental; however, one model assumes that the detrimental effect is the same without regard to degree of disturbance in the recent past, whereas another assumes that the effect is less if the prairie has experienced recent disturbance).

## 5.5. Monitoring protocols

The importance of monitoring in adaptive management applications is universally recognized, so much so that some people seem to think that monitoring resource conditions is sufficient in and of itself to make a project "adaptive." Monitoring certainly does play a critical role by providing the information needed for both learning and evaluation of management effectiveness. But we emphasize again that, by definition, adaptive management involves not just monitoring, but the implementation and integration of multiple components in assessment and adaptation. The value of monitoring in adaptive management springs from its contribution to decision making, and monitoring protocols should be developed with that in mind.

To make monitoring useful, choices of what ecological attributes to monitor, and how to monitor them (frequency, extent, intensity, etc.), must be linked closely to the management situation that motivates the monitoring in the first place. There are always limits on the staff and funding for monitoring, and it is important to choose design protocols that will provide the most useful information within those limits. Protocol design should be based on the purposes of monitoring and the way in which monitoring data will be analyzed.

***Climate change.*** Monitoring should cover the climate variables that are thought to drive system behaviors, as well as the resource attributes and processes that are affected. Monitoring protocols should specify the attributes to be monitored and methodologies to be used. Because long time periods are often involved, a structured monitoring process might include, for example, frequent monitoring of some biological attributes such as mortality and reproduction rates, less frequent monitoring of landscape attributes such as ecosystem types and locations, and monitoring at decadal or longer intervals for features such as directionality and variation of climate drivers.

***Water resources.*** Monitoring protocols for water resources vary depending on the type of aquatic system and the management objectives. Water flows into and out of a standing water body and water movement in a river or stream can be measured continuously or intermittently. Water quality, temperature, clarity, and concentrations of particulate matter can be measured seasonally or year-round. There are many ways to measure biological components such as aquatic vegetation, fish, and other organisms. Surveys can also be used to track human uses and impacts (recreation, subsistence fishing and hunting, aquaculture).

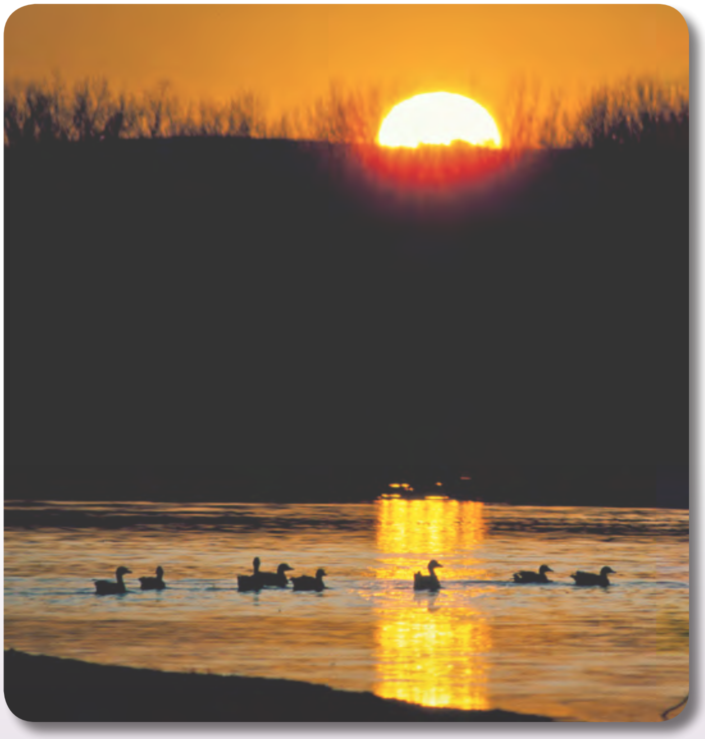
***Energy.*** For energy development and production, monitoring usually involves the timing, extraction, or amount of energy produced by energy facilities. Often, a utility or corporate sponsor commits to do the monitoring. In many if not most cases, the impacts of energy infrastructure and operations on fish, wildlife, and habitats also need to be monitored.

***Human/natural interface.*** Monitoring protocols for projects in this thematic area target ecological variables and processes that are affected by human disturbance and management actions. Efficiency and accuracy of monitoring-based estimates (of system states, vital rates, or resource aggregates such as biodiversity) are important concerns.

### Examples of monitoring protocols

***Coastal wetland impoundments and sea level***

Many national wildlife refuges maintain coastal wetland impoundments that enhance habitat and attract large numbers of waterbirds and other wildlife, but rising sea levels may eventually lead to removal of some impoundments. To track this threat, monitoring of shorebird and waterfowl numbers, habitat extent and condition (vegetation, water levels), and infrastructure management costs could be conducted annually, with periodic monitoring of sea level. The data from monitoring would be used to determine resource status each year and evaluate progress toward achieving objectives, which might include target numbers of waterfowl to be maintained, as well as specific budgetary limits.



***Wyoming Landscape Conservation Initiative***

Oil and gas extraction projects on federally managed lands in Wyoming impinge on habitat of imperiled species such as the greater sage grouse, a candidate for listing under the Endangered Species Act. In the Wyoming Landscape Conservation Initiative, management focuses on conserving and enhancing wildlife habitat in areas surrounding oil and gas extraction operations. In the 1990s various vegetation treatments (burns, herbicides) were used to create a mosaic of sagebrush stands in an attempt to provide preferred habitat for sage grouse. Actual use of the treated habitat by sage grouse is monitored by counting foraging pellets and droppings within belt transects on treatment and control sites.

***Prairie pothole restoration***

The Minnesota Private Lands Program, part of the National Wildlife Refuge System, supports restoration of small privately owned prairie pothole wetlands that were converted to agriculture by draining and filling during the period from the 1950s to the 1980s. Adaptive management of hydrological restoration, sometimes combined with sediment removal, is used to maximize wetland quality for breeding waterfowl. Resource attributes that are monitored include percentage of the pothole filled with water, horizontal interdispersion of vegetation, plant diversity, and invasive species. Monitoring is conducted for 30 minutes per pothole annually for 4 years, and in years 6 and 8 after restoration.

***Solar project siting and permitting***

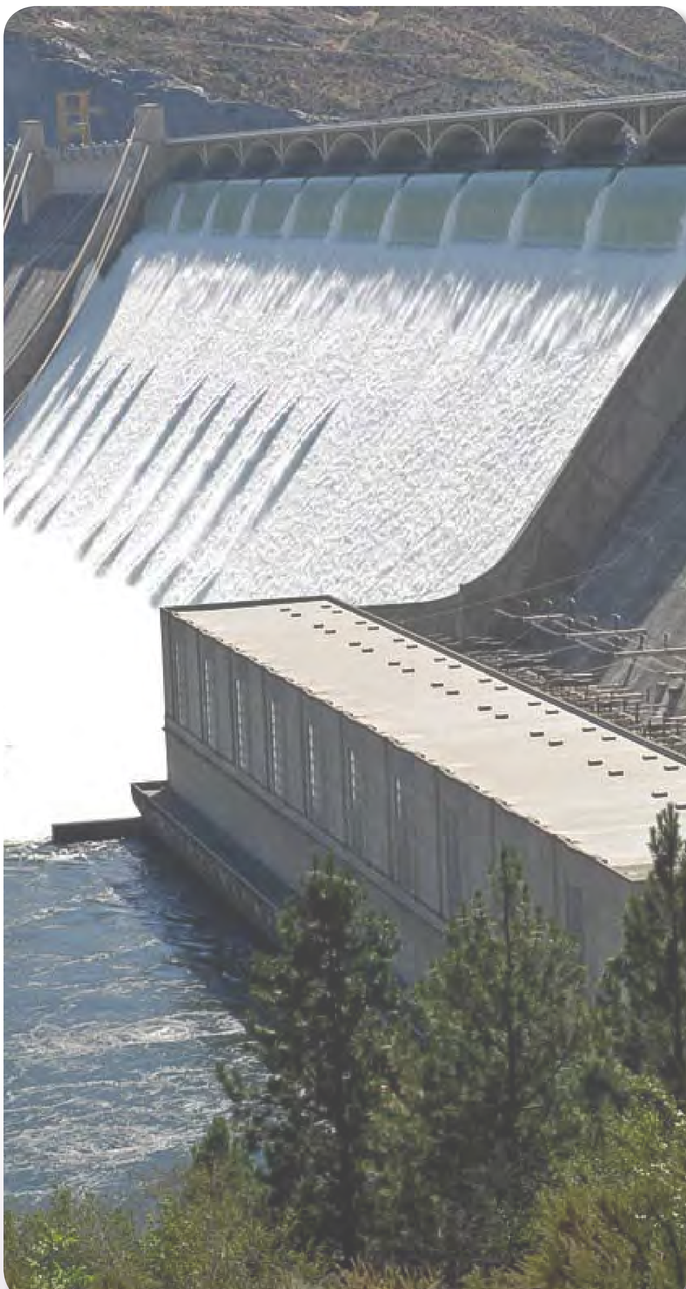
In California, proposed industry-grade solar energy projects range in size from 200 to 3,200 hectares. Almost all the land and resources within a project boundary are affected by the placement of solar collectors, service roads, and rainwater retention basins, which can interfere with desert sand transport cycles. In a project sited to reduce blockage of sand moving across the valley, monitoring could be conducted to evaluate whether the infrastructure configuration meets the objectives of maximizing energy production while minimizing impacts on plants dependent on blowing sand. Attributes monitored could include energy production, establishment of blowing-sand-dependent plants downwind, and sand dune stability.

***Native prairie restoration in national wildlife refuges***

Native prairies in national wildlife refuges of the northern Great Plains are being invaded to varying degrees by plants such as smooth brome and Kentucky bluegrass. By reintroducing disturbance, refuge managers hope to control invasive plants and restore a high proportion of native species. To measure plant community composition, annual belt-transect monitoring on a sample of 25-m transects from each of approximately 120 native prairies provides measures of vegetation composition in four classes: percentage of native grasses and forbs, percentage of smooth brome, percentage of Kentucky bluegrass, and percentage of other plants. These four values are used to assign a particular prairie to one of 16 possible states (for example, one such state is defined as 45- to 60-percent native grasses and forbs with the remainder dominated by smooth brome).

***River temperature and salmonid survival***

Large storage reservoirs behind hydroelectric dams can cause warmer water temperatures, resulting in stress and mortality for salmonid fish and reducing the dissolved oxygen necessary for fish and other aquatic life. Adaptive management to maintain water temperatures and dissolved oxygen at biologically appropriate levels would include monitoring of vertical temperature gradients in the reservoir, water temperatures downstream, and salmonid survival rates. The monitoring data would be used to evaluate effectiveness of management actions (e.g., cold water releases during summer months, reduction of warm water inputs, and water temperature control curtains) and progress toward objectives (e.g., sustaining downstream temperatures below 20°C and increasing salmonid survival).



***Adaptive harvest management***

Adaptive harvest management was developed to deal with uncertainties in the regulation of sport waterfowl hunting in North America. A major component of the process for setting waterfowl hunting regulations consists of data collected each year on population status, habitat conditions, production, harvest levels, and other attributes of management interest. Waterfowl monitoring in North

America is made possible only by the cooperative efforts of the U.S. Fish and Wildlife Service, the Canadian Wildlife Service, state and provincial wildlife agencies, and various research institutions. Among the most important are waterfowl and wetland habitat surveys conducted in the principal breeding range of North American ducks. Waterfowl are also monitored through a large-scale banding program in which individually numbered leg bands are placed on birds, usually just prior to the hunting season. Finally, the Fish and Wildlife Service conducts hunter surveys to determine hunting activity and the size of the waterfowl harvest.

***Fire fuel treatments in the Sierra Nevada***

Millions of hectares of forest in California are at risk from wildfires. Management of fire fuels on Forest Service lands in the Sierra Nevada has generated controversy for decades. To help reconcile conflicts, an adaptive management project is now being used to implement the 2004 Sierra Nevada Forest Plan Amendment. The project evaluates how different forest vegetation treatments can reduce fire spread and intensity within the constraints of maintaining water quality, residential safety, and wildlife habitat for the Pacific fisher and California spotted owl. The project involves reduction of fire fuels in a series of patches with a method of strategically placed treatments at the landscape level. Fire risk reduction, wildlife impacts, and water quality are monitored at two study areas in 1/20 hectare permanent plots set in a 500-meter grid pattern. Data are collected on forest structure and composition as well as shrubs and fuels. Water quality will be monitored in two sub-watershed areas.